

Anthropogenic initiation and acceleration of aeolian dune activity within the northern European Sand Belt and societal feedbacks over the last ~ 2500 yrs

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In North-Western Europe, Pleistocene sand sheets have been re-activated during phases of Holocene deforestation and agricultural land-use. Although there are temporal overlaps between anthropogenic activity and sand sheet re-activation, the root cause and subsequent feedbacks between aeolian activity and societal response remain largely unknown. Here, we seek to establish cause and effect by examining the detailed co-variation in both the timing and magnitude of aeolian and anthropogenic activity through the quantification of Holocene dune sediments in combination with archaeological and pollen records. These records indicate a series of complex phases of aeolian activity followed by landscape stabilization, which we attribute primarily to changing patterns of human impact. We find that a steady increase in dune deposition rates in the Medieval Period corresponds to an increase in settlement activity and deforestation (~ 1000–1500 AD). At their peak, Medieval deposition rates were 3.4-times larger than during the late Pleistocene, which was the period experiencing the most favourable natural conditions for aeolian sediment transport in the past 11600 years. Prior to the Medieval Period, relative land-surface stability (depositional hiatus) persisted from the late Pleistocene until the Roman Iron Age Period (0–400 AD), in which deforestation to fuel iron production had a minor impact on aeolian activity, as indicated by the lowest recorded deposition rate ($0.12 \text{ t/ha/a} \pm 0.02 \text{ t/ha/a}$). Following the Medieval Period peak in aeolian deposition rates, aeolian activity diminishes rapidly, and coincides with the abandonment of nearby human settlement. This can be interpreted as a direct positive feedback in which Medieval agricultural overexploitation crossed sufficient aeolian activity thresholds to render the landscape practically unworkable for cropping agriculture. Based on our findings and a comprehensive review of Northern European sand belt activity, we interpret a very high sensitivity of aeolian activity to past and present human impact, and argue that unsustainable land-use practices have been the cause for widespread settlement abandonment.